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Stephen L. O'Dell
Giovanni Pareschi
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Introduction

The conference *Optics for EUV, X-Ray, and Gamma-Ray Astronomy IV* met August 4—6 in San Diego, California, as part of the SPIE Optics + Photonics 2009 international symposium *Optical Engineering + Applications*. As with previous conferences in this series, it provided an effective forum for discussion of recent progress in imaging and spectroscopic optics for EUV, x-ray, and gamma-ray astronomy. With over 60 papers in 13 sessions, this volume attests to the vitality of research in this field. We thank the conference committee for helping to organize the technical program and for fostering broad participation. We also appreciate the efforts of the SPIE staff in organizing the meeting and in preparing these Proceedings.

In 2009, the *International Year of Astronomy* commemorates the first astronomical observations with an optical telescope, performed 400 years ago by Galileo Galilei. The year 2009 marks significant anniversaries for x-ray astronomy as well. It is the 60^{th} anniversary of the discovery of extraterrestrial x rays (solar corona), which was followed in 1962 by the discovery of extrasolar x rays (Scorpius X-1) and then in 1963 by the first x-ray observations (of the sun) using focussing optics. Further, 2009 is the 50^{th} anniversary of the arrival at American Science & Engineering of Riccardo Giacconi, whose extraordinary vision and persistence fathered modern x-ray astronomy from the early rocket-borne experiments to large orbiting facilities for high-energy astrophysics. Indeed, in 2009 we also celebrate the 10^{th} anniversaries of the Chandra X-ray Observatory and of XMM-Newton.

The Einstein Observatory was the first x-ray-astronomy satellite with a high-resolution focusing x-ray telescope. It, ROSAT, ASCA, and SAX enabled the study of diverse cosmic sources at x-ray energies, thus establishing high-energy astrophysics as a fundamental tool for studying the universe. Currently operating space observatories—Chandra (AXAF), XMM-Newton, Suzaku (Astro-E2), Swift, and Hinode (Solar-B)—demonstrate the importance of focusing optics to x-ray astronomy. Launching within the next 5 years, NuSTAR, Astro-H, and NHXM will extend the power of focused imaging into the hard-x-ray band, improving sensitivity by a couple orders of magnitude.

Collectively, these missions have appreciably advanced technologies for high-angular resolution, large collecting area, high-spectral resolution, and lightweight x-ray optical components. Requirements for the International X-ray Observatory (IXO)—a joint NASA–ESA–JAXA facility-class mission proposed for launch around 2021—are currently stimulating significant progress in developing technologies for lightweight, large-area, precision x-ray mirror systems. Future missions will require further advances to enhance such capabilities for EUV, x-ray, and gamma-ray astronomy. Furthermore, while EUV and x-ray optics continue to be an exciting and rapidly developing field, there is growing interest in introducing focussing techniques into γ-ray astronomy.

TELESCOPE SYSTEMS (Session 1) reports on science goals, concepts, development, and implementation of high-energy telescope systems aboard future sub-orbital or space missions. Some of the papers also serve as an introduction to more detailed papers elsewhere in this volume. Among these are the paper on the IXO system studies and technology preparation and those on the hard-x-ray telescopes for Astro-H and NHXM. Other papers described telescope systems for impending missions—the FOXSI solar hard-x-ray rocket experiment and the Russian–German SRG all-sky-survey—and for future missions—the EXIST black-hole finder.

TELESCOPE DESIGN AND OPTIMIZATION (Session 2) describes design studies to optimize the performance of x-ray telescopes. For impending missions—such as NuSTAR—the design is now complete and implementation is in progress. For planned missions—such as IXO—trades continue to optimize the design and approach that satisfy science requirements within resource constraints. For future missions, design studies range from optimizing the optical prescription for wide-field x-ray telescopes —such as WFXT—to dealing with formation-flight issues.

GRATING SPECTROSCOPY (Session 3) addresses objective gratings for dispersive high-resolution x-ray spectroscopy. The papers propose alternatives to the transmission and in-plane reflection gratings used on previous missions—e.g., Chandra and XMM-Newton, respectively. One is the critical-angle transmission (CAT) grating; the other is the off-plane reflection grating.

DIFFRACTIVE OPTICS (Session 4) relates to the development of (transmission) lenses based upon either (phase) Fresnel zone plates or (Laue-configuration) Bragg diffraction in mosaic crystals. Such techniques enable focusing (concentration or imaging) at much higher energies than is feasible with grazing-incidence optics. Hence, they offer the prospect of focused imaging for γ-ray astronomy, which would dramatically improve sensitivity. In addition, variants of this approach can provide diffractive beam combiners for x-ray interferometry.

MIRROR FABRICATION AND CHARACTERIZATION I–III (Sessions 5–7) are all devoted to technologies for fabricating and characterizing lightweight, precision x-ray mirrors—mainly motivated by IXO's demanding requirements for high throughput and <5″ resolution. In particular, Session 5 reports on technology development of thermally slumped glass mirrors (the NASA baseline for IXO), which is used for NuSTAR's 45″ mirror modules and being improved in the US and Europe, toward IXO's 5″ systems-level requirement. Session 6 covers technology development of silicon pore optics (the ESA baseline for IXO), which is being actively pursued by European industry under ESTEC's guidance. Session 7 addresses technologies for cost-effective manufacturing of durable, precisely figured mandrels for mirror replication—by thermal slumping, electroforming, or other process. The session also touches upon polishing and maintaining supersmooth surfaces, which some applications—especially, multilayer-coated hard-x-ray optics—require.

ATMOSPHERIC CHERENKOV TELESCOPES (Session 8), for the first time, reports on visible-light (normal-incidence) mirrors for ground-based telescopes used to detect very-high-energy (≈0.1–100 TeV) γ rays from cosmic sources—via Cherenkov radiation from γ-ray induced electromagnetic showers in the atmosphere. Ground-based γ-ray astronomy requires a next-generation telescope array—such as the proposed (European) CTA or (US) AGIS—comprising numerous telescopes with a very large total collecting area (10,000 m^2), to obtain the desired sensitivity and source-location accuracy. The telescopes need not have a resolution better than 1′ or so, but must be very durable and be manufactured at a much lower cost per unit area than traditional ground-based observatories. Replicated segmented mirrors, fabricated using processes like those being developed for x-ray astronomy, can fulfil this requirement for low areal cost.

MIRROR COATING (Session 9) concerns the coating of EUV mirrors and soft- and hard-X-ray mirrors, with primary emphasis on multilayer coatings—both periodic for normal incidence and graded for grazing incidence. Other topics covered in the session include characterization of coated surfaces, patterned coatings for silicon-pore optics, and differential deposition to correct figure errors.

ALIGNMENT AND MOUNTING (Session 10) covers technical issues in alignment, mounting, and integration of lightweight x-ray mirrors into a mirror module or an assembly. Naturally, much of the development effort is directed toward the demanding requirements of IXO, which is to utilize either silicon-pore optics (ESA baseline) or slumped-glass mirrors (NASA baseline). However, accurate alignment and minimal-distortion mounting are critical issues for all lightweight precision optical systems.

ACTIVE OPTICS (Session 11) reports on the growing interest in active controlled deformation of mirrors to correct figure errors, thus improving the angular resolution for EUV and x-ray telescopes. This method, now widely used for ground-based optical telescopes and for focusing synchrotron-generated x rays, is particularly demanding for the mass-constrained mirror systems needed for space observatories. For highly nested grazing-incidence mirror assemblies, applying this approach is even more challenging: lacking room for a reaction structure, bimorph deformation through zoned piezo-electric coatings seems the most promising approach.

PERFORMANCE MODELING (Session 12) and PERFORMANCE TESTING (Session 13) deal with the identification of effects that affect the performance of an optical system and relevant modelling, simulations (including ray traces), and/or testing to assess the impact of these effects or to predict performance. Several papers address issues such as contamination, epoxy materials and application, (static and dynamic) optical-bench deformation, surface smoothness, and space-environment degradation of multilayer coatings. Others reported the results of x-ray imaging performance predictions and/or testing of specific mirror modules or telescopes.

Stephen L. O'Dell
Giovanni Pareschi